CS 6453: Haven

Soumya Basu
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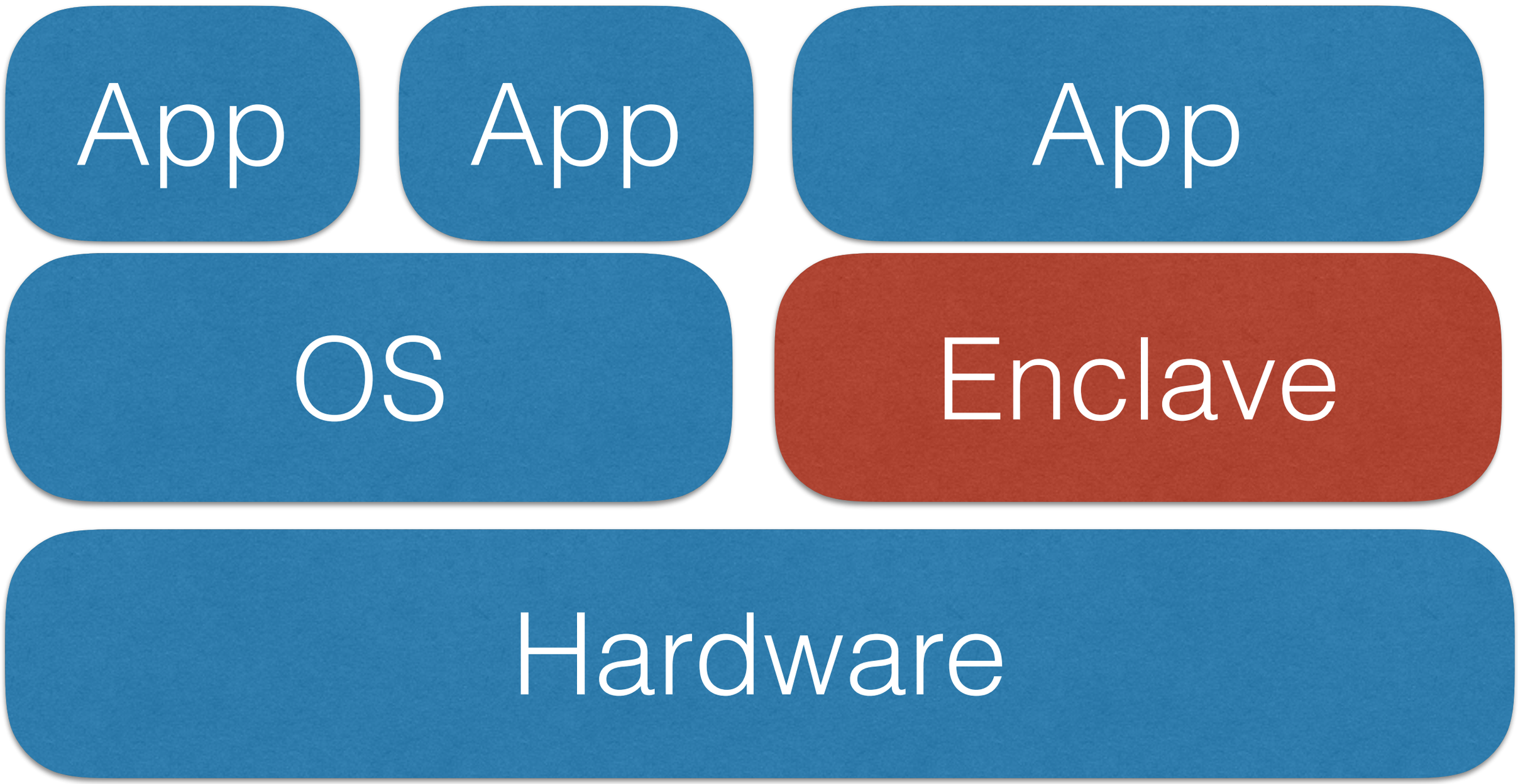
Motivation

- Applications are being migrated to the cloud
- People want to outsource sensitive applications there as well
  - User data, Medical Records, Private Keys, etc.
- Need to trust the cloud provider to keep things hidden and secure…
  - Not always possible (e.g. Aurora attacks)

New Technology

- Intel SGX- New Secure Instructions on Intel Chip



Hardware Isolation

- Hardware Security Modules offer limited functionality
- Trusted Platform Modules have two drawbacks
  - Vulnerable to relatively easy hardware attacks
  - Bad multiplexing between secure/insecure environments
- Two approaches to multiplexing:
  - Time-multiplex the entire page cache (inefficient!)
  - Attest to the OS code that is running (prevents upgradability)

Software Isolation

- General approach: protect apps against untrusted OS
- Systems that use this approach are vulnerable to Iago attacks
  - Only defense: write a shield module against OS
- Haven does something similar, but leverages SGX

Untrusted Cloud

- Can use crypto techniques to outsource work to cloud
  - Only works for new applications
  - Very hard to reason about security

Where is this work new?

- Define the concept of shielded execution, see how SGX plays into this picture
- Unmodified applications, which means OS functionality has to be untrusted
  - Private scheduling of threads
  - Virtual Memory Management untrusted
  - Encrypted and Integrity-protected file system

Shielded Execution

- Confidentiality
  - Execution of a program is a black box
  - Inputs and outputs observable, no intermediate state
    - Why is this good enough?
- Integrity: System cannot change program behavior
- What about availability?

Threat Model

- Malicious cloud
  - Controls all code outside of client app code
    - Software stack, Host OS, scheduling, etc.
- Intel is trustworthy, secure hardware is secure
- Side channel attacks not covered

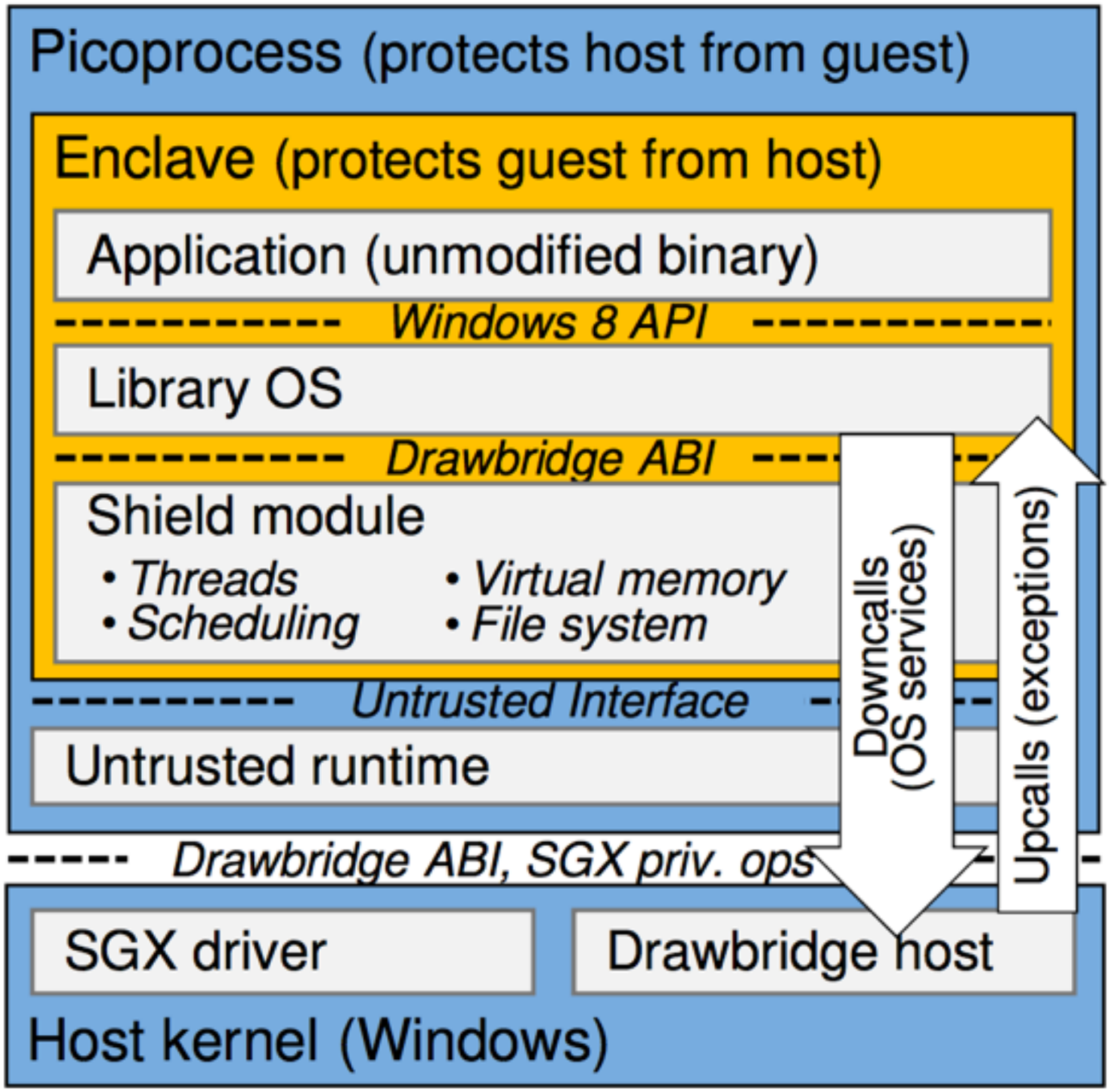
Intel SGX

- Memory Protection: Integrity and Confidentiality of memory handled by SGX
  - SGX allows host OS to page in/out entries from page table
- Attestation: Can verify remotely that it is running the right code

Intel SGX

- Enclave Entry and Exit
  - Some exception information leaked to the OS
    - Allows OS to handle resource management
  - Some info hidden by replacing register info with dummy info
- Dynamic Memory Allocation: Allow OS and enclave to increase memory for app

Architecture

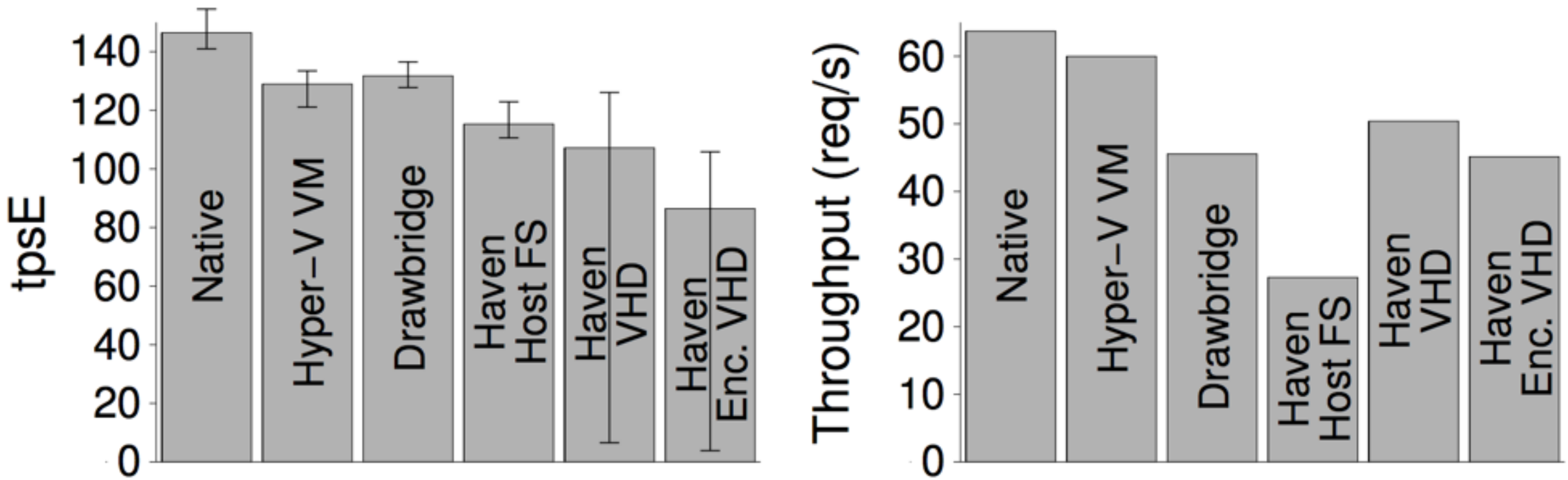


Component	Lines of Code
Library OS	millions
Shield module	23095
Untrusted runtime	7446
SGX driver	4520

Shield Module

- Primary Functionality: Protect against Iago attacks
  - Ensure that OS level functionality is meeting spec
- Reimplements Virtual Memory, Storage and Threading from the OS so that it is trusted
- Handles some other calls as well:
  - Random number generation, Windows “forks”

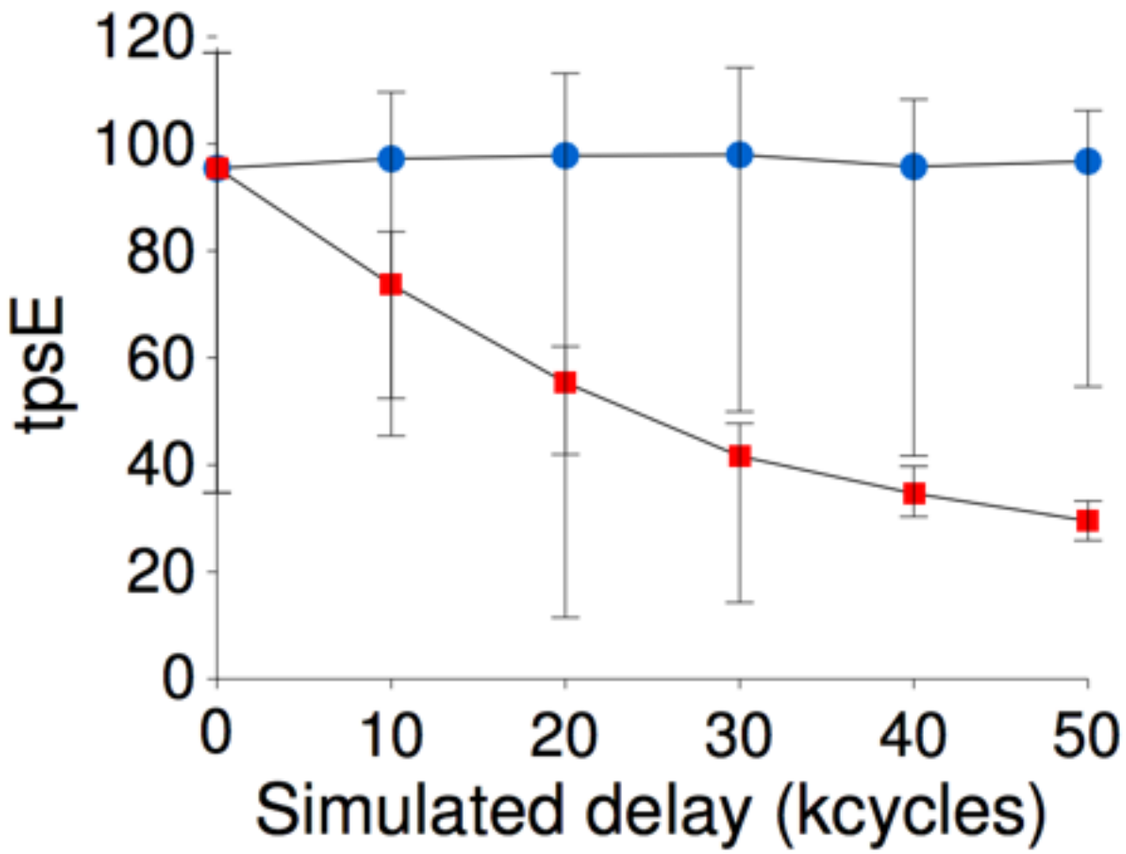
Evaluation



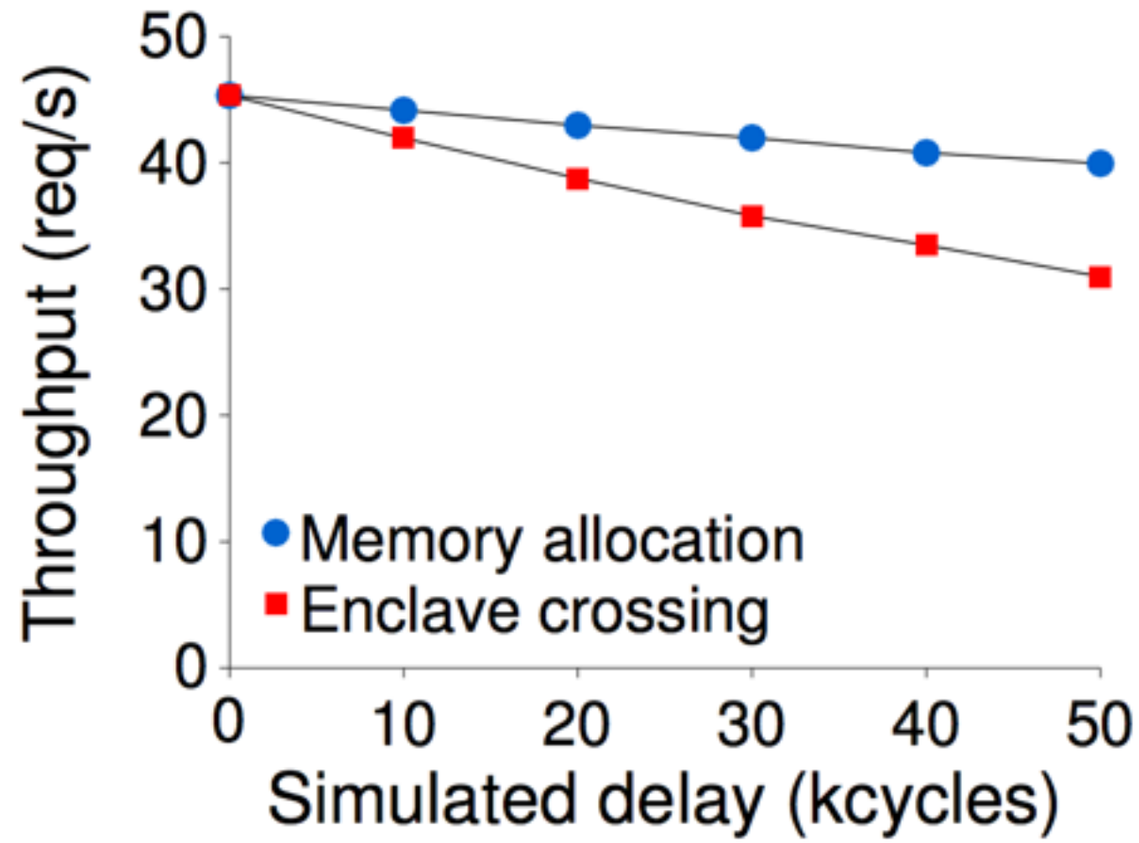
(a) SQL Server, TPC-E (b) MediaWiki on Apache

Figure 4: Performance breakdown

Evaluation



(a) SQL Server, TPC-E



(b) MediaWiki on Apache

Figure 5: Sensitivity to SGX instruction overhead

Limitations

- Lots of engineering effort
  - Many of the research insights were not surprising
  - Not really in the spirit of SGX
- Trusted Computing Base is HUGE
- Vulnerable to side channel attacks
  - Other systems completely broken with this

What Next?

- How do we outsource computation effectively to the cloud?
- What role does trusted hardware actually play in this space?
- How do we deal with legacy applications?